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ANALYSIS

Bioeconomic analysis of herpetofauna road-kills in a Florida state park

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ABSTRACT

Road-kills are a major cause of mortality for a wide variety of herpetofauna, but management decisions on remediation procedures for reducing losses are based in economic realities. Because funding is finite for species conservation, bioeconomic analysis can assist in justifying, evaluating, and maximizing returns on conservation expenditures, especially for low-profile species such as herpetofauna. Here, we present a bioeconomic analysis of road-killed herpetofauna in Jonathan Dickinson State Park, Florida. Road surveys were conducted daily for four years to identify and enumerate the numbers of each reptile and amphibian species killed by vehicles. Conservative individual valuations applied to the losses formed the basis of a benefit–cost analysis aimed at identifying the thresholds at which remediation expenditures would be justified. We found an average of 64 reptiles and amphibians were killed/year, justifying conservation expenditures up to $32,000/year. However, if less conservative valuations were applied, especially for threatened and endangered species, justifiable expenditures rise dramatically.

1. Introduction

Road-kills of herpetofauna are a major cause of mortality for a wide variety of taxa (Ashley and Robinson, 1996; Haxton, 2000; Trombulak and Frissell, 2000; Hels and Buchwald, 2001). However, management decisions to implement actions for reducing losses are based in economic realities, and herpetofauna often are low-profile species. Funding is finite for species conservation and must be carefully applied to maximize its positive impact. Economic valuation and analysis of the losses can assist in evaluation and justification of remediation activities. We collected four years of herpetofauna road-kills from a south Florida state park. We economically valued those losses and conducted benefit–cost analyses to determine at what expenditures potential management actions would be justified.

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2. Methods

2.1. Study area

Jonathan Dickinson State Park (JDSP) is a 4644.1 ha mixed-use state park located in Hobe Sound, on Florida's southeast coast. JDSP is a mix of uplands and wetlands, consisting mostly of seven vegetation community cover types: wet pine flatwoods (1983.8 ha), scrub (935.2 ha), strand swamp (370.9 ha), wet prairie (351.8 ha), scrubby flatwoods (234.8 ha), depression marsh (176.5 ha), and floodplain swamp (117.4 ha) (Office of Park Planning, GIS data). Approximately 10 km of paved, two-lane roads traverse the park, with speed limits ranging from 24.2 to 48.4 km/h. Fifty four native reptile and amphibian species are known to inhabit the park. Among these, five are either state and/or federally listed as threatened, endangered or a species of concern (Florida Department of Environmental Protection, 2000).

2.2. Surveys

A daily (7 days/week) road-kill survey was conducted during 1995–1998 by JDSP Park Rangers and consisted of slowly searching road surfaces (ca. 8–24 km/h) for dead wildlife, as reported for other state parks (Smith et al., 1994; Bard et al., 2002; Smith et al., 2003). Surveys were initiated between 7:45 and 8:15 a.m. Reptile and amphibian (as well as other vertebrate wildlife taxa) struck by vehicles were examined. Road-kills were identified and recorded to the species level, if possible. Their locations were noted to avoid being double counted on subsequent days.

2.3. Economic valuations

Determination of monetary values for wildlife species is not a straight-forward nor precise process. As an illustration, values of endangered or threatened species have been deemed "incalculable" in U.S. Supreme Court case law (Tennessee Valley Authority vs. Hill, 1978), the opinion going so far as to say "it would be difficult for a court to balance the loss of a sum certain – even $100 million – against a congressionally declared 'incalculable' value, even assuming we had the power to engage in such a weighing process, which we emphatically do not." Despite that assessment, astronomically high monetary species valuations would be unlikely to be widely viewed as credible. Nevertheless, conservative monetary values for wildlife species can be estimated.

State wildlife and fisheries management agencies apply economic values based on contributions to the economy by individual game species (Bodenchuk et al., 2002). These economic values serve as the basis for civil financial penalties for illegal kills resulting from poaching, environmental contamination, or other "takes" (Bodenchuk et al., 2002). Except in rare cases, reptile and amphibian species do not have civil financial penalties assigned in relation to their contributions to the economy as "renewable" resources, because they are rarely exploited in a financially measurable fashion such as sales of hunting or fishing licenses and sportsman equipment. While not exploited as a "renewable" resource, these species are usually protected with civil penalties set forth legislatively.

Legislatively based species valuations have proven useful in a variety of applications for analyzing the economics of actual or potential management actions aimed at species conservation (e.g., Engeman et al., 2002, 2003, 2004; Shwiff et al., 2003; Smith et al., 2003). Many species may have more than one value available from multiple enabling legislations (e.g., United States federal and individual state laws). Multiple applicable civil penalties pose a dilemma as to which to incorporate into an economic analysis. In Florida, minimum monetary values for wildlife resources (penalties assessed for illegal "take") are specified in both statute and administrative code (Florida Statutes 370.021(5)d–f; Florida Administrative Code 39-27.002, 39-27.011, and 39-4.001). Likewise, federal laws also are applicable to some species which impose greater values (e.g., Endangered Species Act). We used the State of Florida wildlife values (Engeman et al., 2002; Shwiff et al., 2003; Smith et al., 2003) for our economic analysis, where the Wildlife Code of the State of Florida specifies up to a $500 fine for "take" applicable to all wildlife in section 39-4.001 F.A.C. Given the variety of herpetofauna analyzed by this study, we also applied a range of conservative values in a benefit–cost analysis. A value of $250 was used to represent half of the civil penalty value and $100 was used to examine the benefits and costs of potential programs given extremely conservative values for the herpetofauna. This range of values provided a more extensive evaluation of

Table 1 – Species and dollar value of reptile and amphibian road-kills, 1995–1998, Jonathan Dickinson State Park, Florida

Species		Dollar value		
	No. lost	$100	$250	$500
Florida box turtle	3	$300	$750	$1500
Gopher tortoise	15	$1500	$3750	$7500
Unidentified aquatic turtle	1	$100	$250	$500
Florida scrub lizard	1	$100	$250	$500
Glass lizard	5	$500	$1250	$2500
Dusky pygmy rattlesnake	12	$1200	$3000	$6000
Eastern diamondback rattlesnake	4	$400	$1000	$2000
Eastern coral snake	6	$600	$1500	$3000
Rough green snake	22	$2200	$5500	$11,000
Black racer	42	$4200	$10,500	$21,000
Eastern coachwhip	5	$500	$1250	$2500
Eastern corn snake	36	$3600	$9000	$18,000
Scarlet kingsnake	4	$400	$1000	$2000
Florida pine snake	2	$200	$500	$1000
Eastern indigo snake	1	$100	$250	$500
Garter/ribbon snakes	41	$4100	$10,250	$20,500
Eastern mud snake	1	$100	$250	$500
South Florida swamp snake	1	$100	$250	$500
Florida water snake	1	$100	$250	$500
Unidentified snakes	10	$1000	$2500	$5000
American alligator	4	$400	$1000	$2000
Southern leopard frog	2	$200	$500	$1000
Pig frog	1	$100	$250	$500
Gopher frog	1	$100	$250	$500
Unidentified anurans	35	$3500	$8750	$17,500
Total	256	$25,600	$64,000	$128,000
Average/year	64	$6,400	$16,000	$32,000

Table 2 – Annual benefit–cost ratios for differing management costs to avert an average of 64 amphibian and reptile road kills in Jonathan Dickinson State Park, Florida, where animals are valued at $100, $250, and $500 each

Management cost (annual)	Value of annual loss		
	$6400	$16,000	$32,000
$1000	6.4	16	32
$2500	2.56	6.4	12.8
$5000	1.28	3.2	6.4

the potential efficiency of management programs given different cost scenarios.

2.4. Benefit–cost analysis

The benefit–cost analysis (BCA) follows the framework outlined in Engeman et al. (2002, 2003) and Shwiff et al. (2003). The BCA of herpetofauna management involves estimating the monetary value of the benefits measured in the dollar value of animals saved by reduced road-kills versus the costs measured in the amount spent to reduce road-kills. In this study, the number of animals saved each year represents the benefits of a hypothetical road-kill management program. Benefits were calculated by multiplying the number of animals saved each year by the value of each individual animal ($100, $250 and $500). A range of values ($1000, $2500 and $5000) was also used to estimate the annual total cost of a road-kill management program.

The benefit–cost ratios (BCRs) are calculated using the standard format of the ratio of benefits to costs (Loomis and Walsh, 1997; Boardman et al., 1996; Nas, 1996; Zerbe and Dively, 1994; Loomis, 1993). In general, the BCRs for this analysis were calculated from the equation

$$\mathrm{BCR} = \frac{\text{Total Value of Animals Saved}}{\text{Road} - \text{kill Management Costs}} \tag{1}$$

A value of 1.0 indicates no net benefit or cost (dollar savings in animals saved). For example, the annual BCR for reducing road-kill by 96 animals each valued at $500 with management costing of $1000 would be 48, i.e., the value of the animals saved is 48 times greater than the cost of management for that year.

3. Results

Two hundred fifty six individual animals, representing 2 turtle species, 2 lizard species, 15 snake species, American alligators, 3 frog species and various unidentified aquatic turtles, snakes and anurans were recorded as road-kills during the study period (Table 1), averaging 64 animals per year. Using the three values for herpetofauna ($100, $250, and $500) to estimate the benefits of road-kill management provided an economic sensitivity analysis. Total losses using the three animal values were $25,600, $64,000, and $128,000, respectively. Had we substituted the Endangered Species Act value of $25,000 for the eastern indigo snake (*Drymarchon corais*), the total economic loss would have been $50,500, $88,750 and $152,500, respectively. The prevention of some or all of these losses through a management program provides an economic benefit.

Substituting the appropriate values into Eq. (1) and completing this process for all values of animal and management costs yields the annual BCRs in Table 2. This assumes all 64 animal losses per year would have been averted. A sensitivity analysis varying the number of animals saved per year provides an alternative approach to estimating the BCRs of a hypothetical management program. Table 3 examines three scenarios. Each scenario assumes an animal value of $100, $250 or $500. A range is provided under each scenario for the number of animals saved and program costs. This allows for sensitivity analysis to determine the conditions under which the program is economically efficient.

Under the first scenario (panel A), each animal is valued at $100. The benefit–cost ratios (BCRs) range from 0.2 to 6. The best BCR (6) results from the lowest program cost of $1000 and 60 animals saved annually. The worst BCR (0.2) results from the highest program cost of $5000 and only 10 animals saved annually. A program scenario is economically inefficient when BCR values are less than one, which indicates that the costs exceed the benefits. There are six such scenarios presented in panel A. There are two breakeven points (BCR = 1) under this first scenario, when program costs are

Table 3 – A benefit–cost sensitivity analysis for averting amphibian and reptile road kills in Jonathan Dickinson State Park, Florida, where the management costs, number of animals saved and values of animals are varied

Panel A: benefit–cost ratios at $100/animal				Panel B: benefit–cost ratios at $250/animal				Panel C: benefit–cost ratios at $500/animal			
Number saved	Management costs			Number saved	Management costs			Number saved	Management costs		
	$1000	$2500	$5000		$1000	$2500	$5000		$1000	$2500	$5000
10	1	0.4	0.2	10	2.5	1	0.5	10	5	2	1
20	2	0.8	0.4	20	5.0	2	1.0	20	10	4	2
30	3	1.2	0.6	30	7.5	3	1.5	30	15	6	3
40	4	1.6	0.8	40	10.0	4	2.0	40	20	8	4
50	5	2.0	1.0	50	12.5	5	2.5	50	25	10	5
60	6	2.4	1.2	60	15.0	6	3.0	60	30	12	6

Management costs with benefit–cost ratios >1 are economically justified as the returns exceed the financial outlay.

$1000 and 10 animals are saved annually and when program costs are $5000 and 50 animals are saved annually. Under each of these conditions there is no net program benefit. All BCRs greater than one indicate that the benefits of the program exceed the costs, which represents economic efficiency. There are ten such scenarios presented in panel A.

The second scenario presented in panel B represents an animal value of $250. BCRs ranged from 0.5 to 15. With a higher animal value the number of inefficient points is diminished to only one, when program costs are $5000 and only 10 animals are saved annually. As in panel A there are two breakeven points presented in panel B, when program costs are $2500 and only 10 animals are saved annually, and when program costs are $5000 and 20 animals are saved annually. The number of efficient points jumps dramatically to 15 under this scenario.

The highest animal value of $500 is used in the final scenario presented in panel C. In this scenario there is only one breakeven point at a program cost of $5000 and only 10 animals saved. All of the other scenarios are economically efficient. The highest BCR indicates that benefits are 30 times greater than the costs, and at the very worst case the benefits equal the costs.

4. Discussion

A variety of management actions can be implemented to reduce reptile and amphibian road-kills. These can range from greater enforcement of speed limits to provision of structural devices to deter herpetofauna from the roadways. For example, wildlife underpasses below roadways have been retrofitted on micro scales (Jackson and Tyning, 1989), and grandiose scales (Foster and Humphrey, 1995), with varying degrees of success and costs. Benefit–cost ratios of management actions to protect wildlife can be calculated and considered in the manner of Engeman et al. (2002, 2004) and Shwiff et al. (2003) so that they are justified in both a biological, and increasingly economic, conservation arena. This will justify testing and use of innovative techniques to further reduce traffic-related mortality, especially for (higher valued) critically imperiled herpetofauna taxa.

For JDSP, there was an average of 64 herpetofauna road-kills per year with an average annual valuation conservatively ranging from $6400 to over $32,000. Also, the number of road-kills observed undoubtedly is a conservative figure. Even though the roads were searched daily, some road-kills likely were lost to scavenging or obliteration by traffic, or otherwise rendered impossible to observe. Moreover, a proportion of animals involved in collisions with vehicles die off of the road where they would not be observed during road surveys. Nevertheless, the dollar amounts provide baseline figures for evaluating expenditures proposed to reduce losses. A hypothetical benefit–cost analysis allows for a case by case analysis of the possible expenditures needed to reduce losses to a level that would result in both economic efficiency and conservation benefits. Varying the animal values, program costs and number of animals saved annually provides a sensitivity analysis allowing the examination of a wide array of management strategies simultaneously. Wildlife managers can identify the best conservation strategy after determining the program costs and animal value.

By necessity, economic analyses take a "shopping cart" approach to valuing species, whereby a "price tag" is applied to the individual of each species. The credibility of an analysis hinges on the logical application of a valuation procedure. Conservative benefit–cost analyses using lower species values tend to lead to greater acceptance of the results, but should be accompanied by the knowledge that the actual benefit–cost ratio could be much higher. The use of a range of values provides a more robust analysis that allows for the examination of results under varying cost conditions. However, estimated replacement costs do not compensate for the immediate loss of biotic potential within demes, nor for the more consequential, irretrievable loss of pooled genetic variation through subsequent generations. Unfortunately, it is impossible to ascribe monetary value to the loss of random mating events and the infinite possibilities for genetic recombination associated with them.

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